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A Low-Frequency Limitation of FACT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The inapplicability of the Fast Asymptotic Coherent Transmission (FACT) ray trace model at 14 Hz is demonstrated by comparison with normal mode calculations whose predictions have been experimentally confirmed.

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A LOW-FREQUENCY LIMITATION OF FACT

The Fast Asymptotic Coherent Transmission (FACT) model [1,2] is a corrected ray theory model for calculating acoustic transmission loss (TL) in the ocean. Although it is generally realized that as a ray model FACT is more accurate at high frequencies, the model has been employed for frequencies into the infrasonic spectrum. The purpose of this report is to document a low-frequency case wherein the predictions of FACT are qualitatively incorrect when compared with those of a wave theory calculation.

The ocean environment was described in the calculations as follows. In the wave theory calculation, the sound speed C as a function of depth in meters is given by

$C(0) = 1539$ m/s	(ocean surface),
$C(1100) = 1485$ m/s	(SOFAR axis),
$C(5500) = 1552$ m/s	(ocean bottom).

At intermediate depths we take C^{-2} to be a linear function of depth. The result is an approximately bilinear profile having a thermocline, SOFAR channel, and depth excess. For the FACT calculation, 42 points along the above profile were calculated and used to describe the profile.

The ocean bottom was modeled as an absorber or scatterer which directed the incident energy away from the direction of propagation. This was accomplished in the FACT model by disregarding those rays which intersected the bottom. In the wave model, the bottom effect was simulated by calculating the modes as though the bottom were a hard reflector and then dropping from the modal summation the modes whose phase velocity exceeded the speed of sound at the bottom.

Calculations were performed for two frequencies and two source depths in an effort originally aimed at modeling an experimental acoustic TL curve [3]. The input parameters to the calculations were:

source depths	21 m, 104 m,
receiver depths	1100 m,
source frequencies	13.86 Hz, 110.85 Hz.

The dark and light lines in the figures refer respectively to the high and low frequencies.

Figure 1 shows the TL for a source depth of 104 m as calculated with a normal mode separation of the wave equation implemented on a digital computer. Examination of this figure reveals that the low-frequency energy is carried by two groups of modes which produce zones of constructive interference every 34.7 n.mi. and 36.3-n.mi., respectively. At the higher frequency, zones of constructive interference appear only with the 36.3 n.mi. period. The TL curve of Fig. 2 shows the same effect when both sources are at the 21-m depth.

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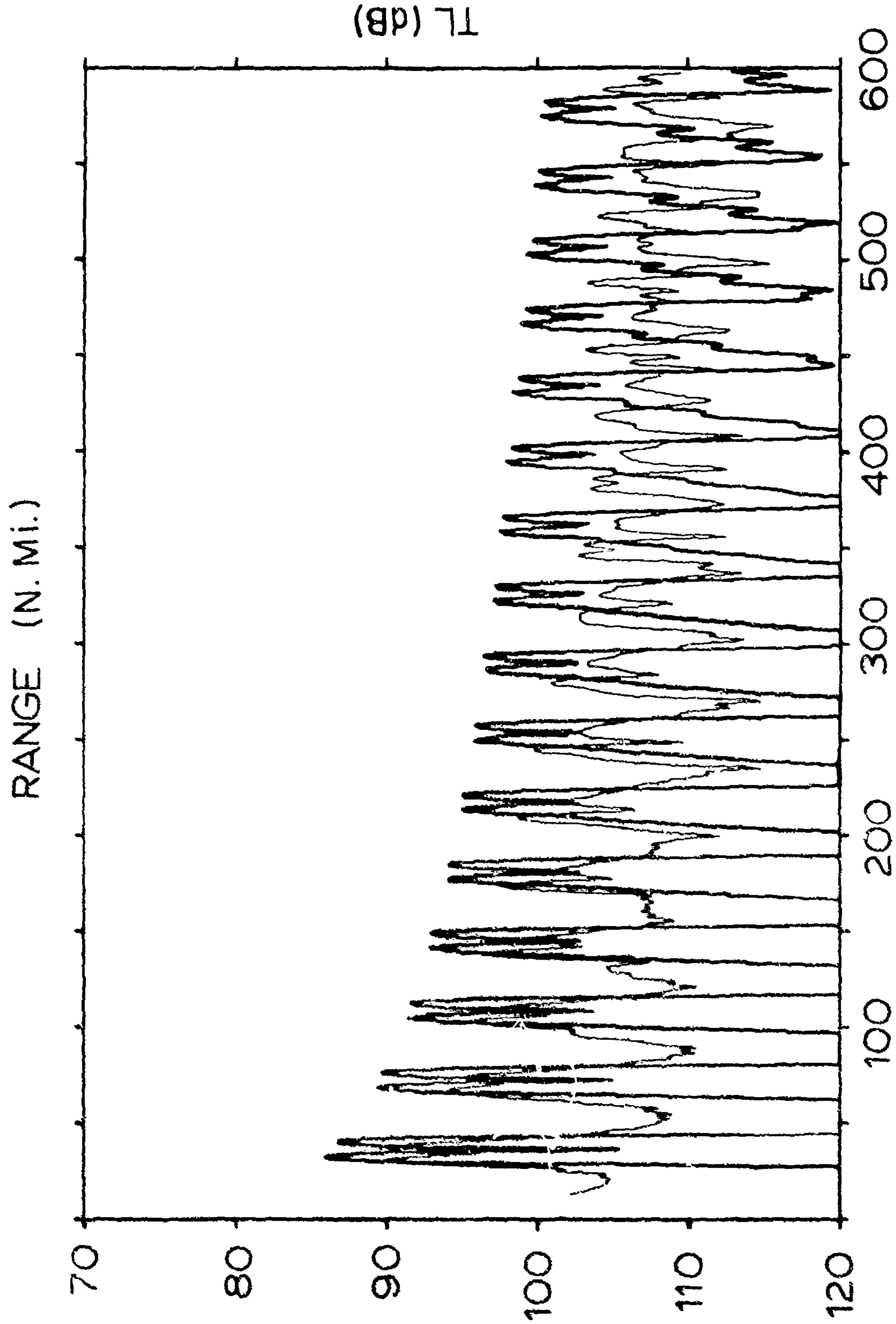

Fig. 1 — Normal mode calculation of TL (dB) vs Range (n.mi.) for source depth of 104 m.

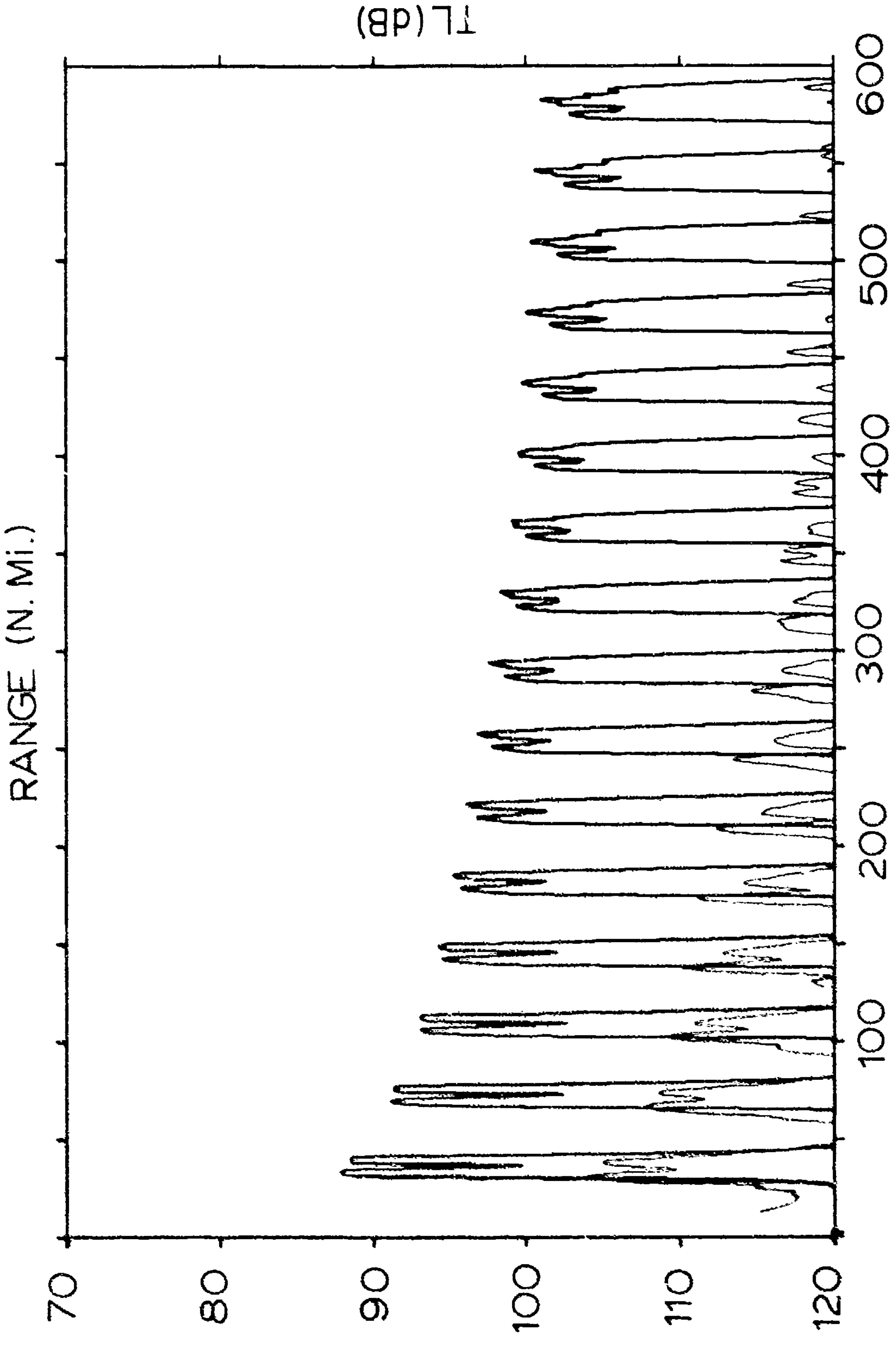

Fig. 2 — Normal mode calculation of TL (dB) vs Range (n.mi.) for source depth of 21 m.

Figures 3 to 8 show the results of the FACT calculations. All combinations of source depth, frequency, and type of ray addition (incoherent, semicoherent, fully coherent) are represented. Although the high-frequency FACT calculations produce convergence zones whose positions agree with those produced by the high-frequency normal mode calculations, none of the FACT calculations shows the aforementioned low-frequency effect.

A normal mode model which allows for discontinuous profile changes in range has been developed and exercised in order to test its predictions against experiment [4]. Figure 9, which was taken from Ref. 4, shows the TL calculated using, not the environmental parameters given earlier, but only archival sound speed and bottom characteristics for the geographic area of the experiment of Ref. 3. The first 700 km of Fig. 9 again show the double periodicity in the low-frequency TL curve not modeled by FACT.

As explained in Ref. 3, the additional low-frequency TL peaks with a period of 34.7 n.mi. are due to the excitation of modes whose phase velocities are less than the speed of sound at the surface. These modes correspond to energy traveling via purely refracted (RR) paths. The discrepancy between ray and wave models thus cannot be attributed to different methods for treating the bottom. Rather, the problem seems to lie in the insufficient allowance by FACT for RR excitation by a low-frequency source located in the thermocline near the surface. The reality of the additional low-frequency TL peaks with period 34.7 n.mi. has been confirmed in the experimental data reported in Ref. 3.

I am grateful to Dr. John Hanna, who had the FACT model run with the given inputs.

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3. A.N. Guthrie, et al., "Long-Range Low-Frequency CW Propagation in the Deep Ocean: Antigua-Newfoundland," J. Acoust. Soc. Am. 56, 58-69 (Jul. 1974).

4. K.E. Evans, "A Normal Mode Model for Estimating Low-Frequency Acoustic Transmission Loss in the Deep Ocean," Ph.D. Thesis, Naval Postgraduate School, Monterey, California (Sept. 1975).

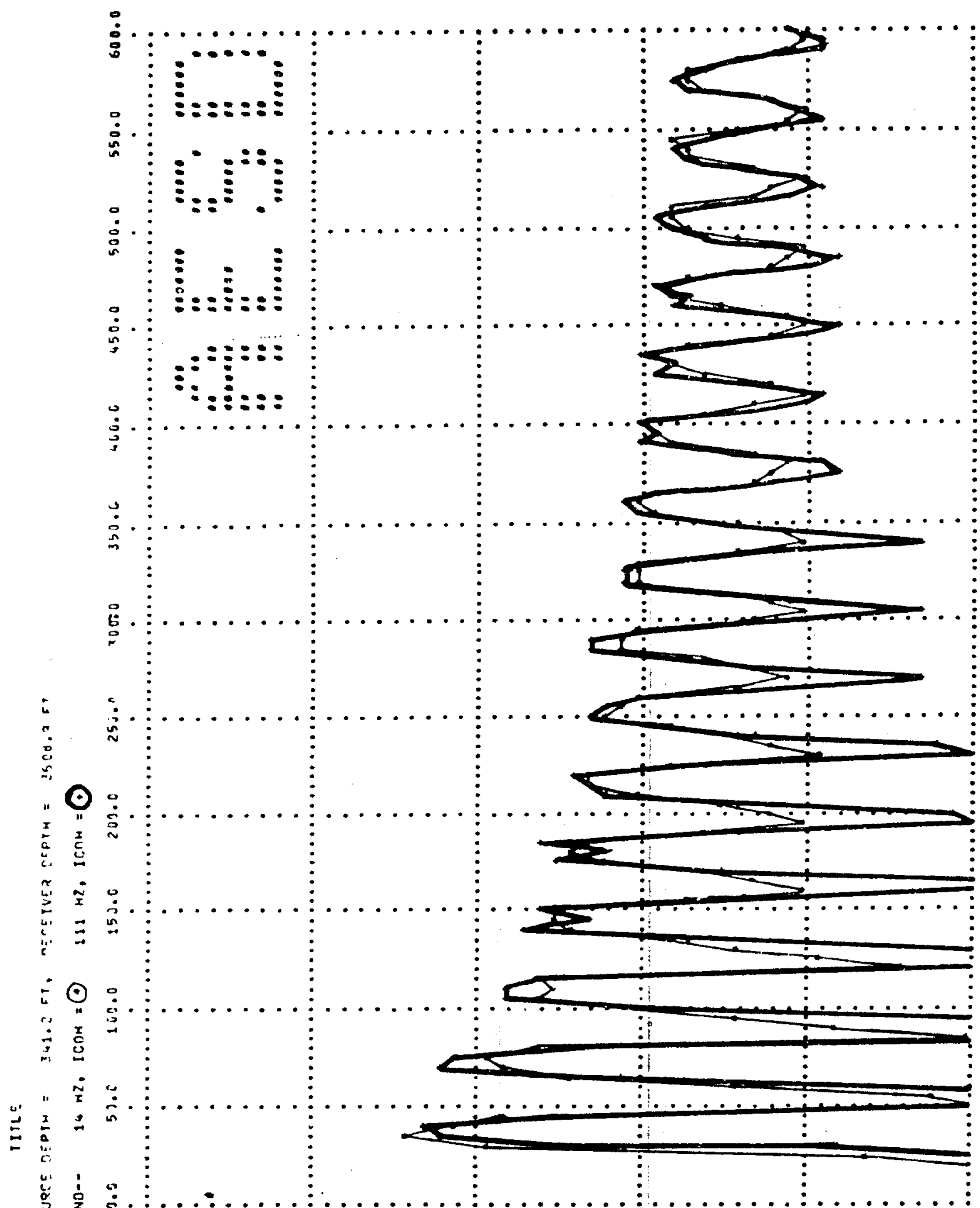

Fig. 3 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 104 m with incoherent summation of rays.

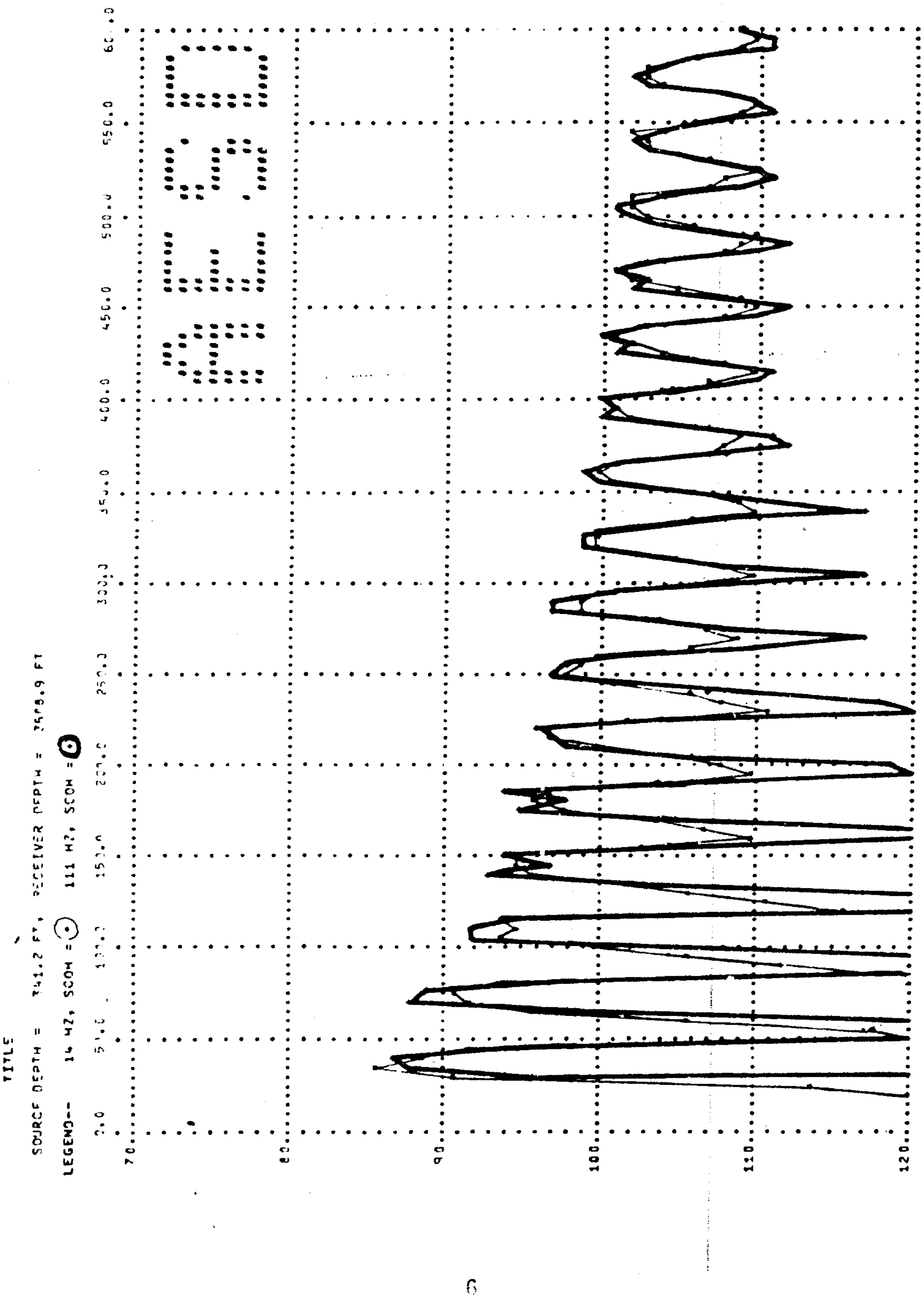

Fig. 4 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 104 m with semicoherent summation of rays.

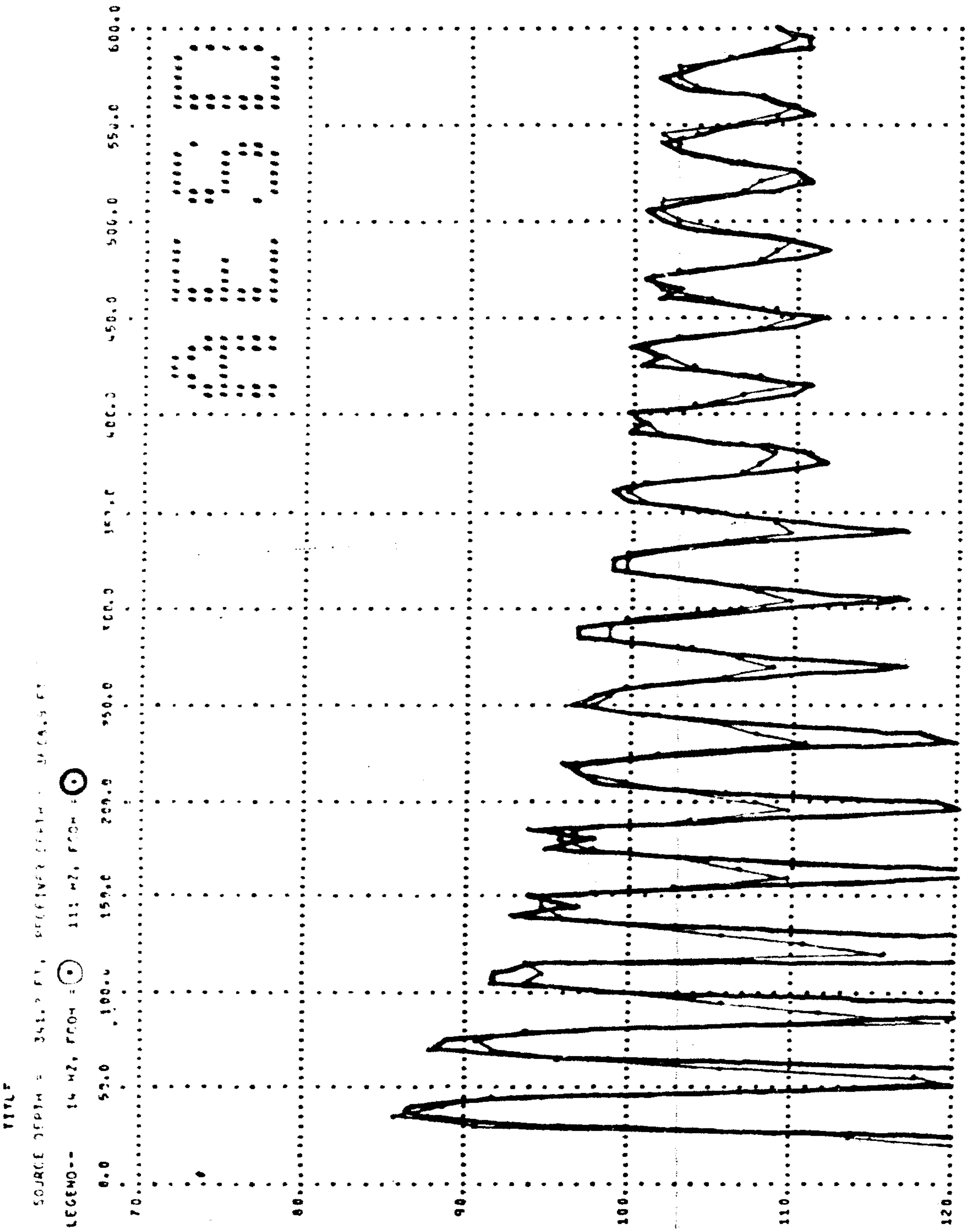

Fig. 5 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 104 m with fully coherent summation of rays.

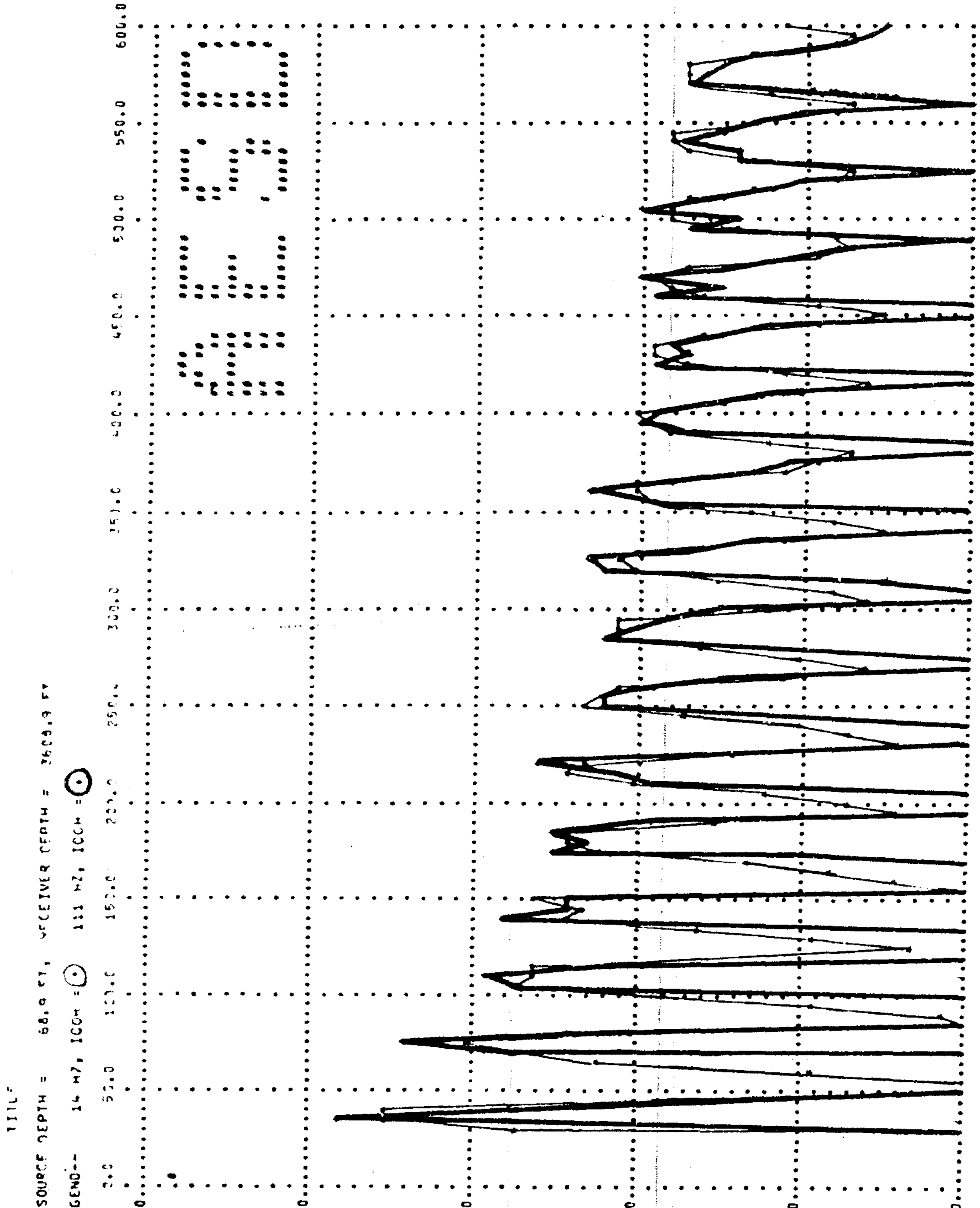

Fig. 6 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 21 m with incoherent summation of rays.

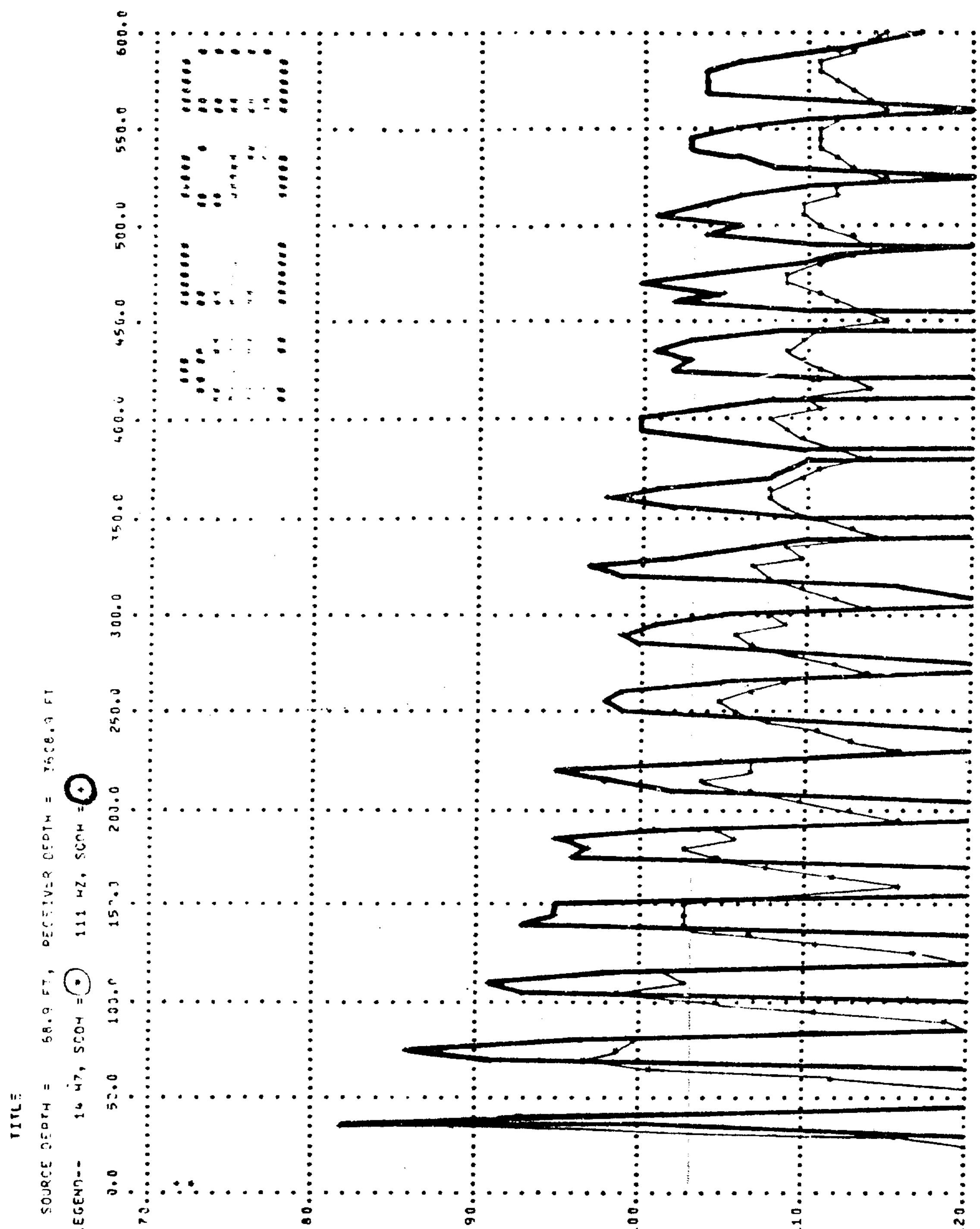

Fig. 7 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 21 m with semicoherent summation of rays.

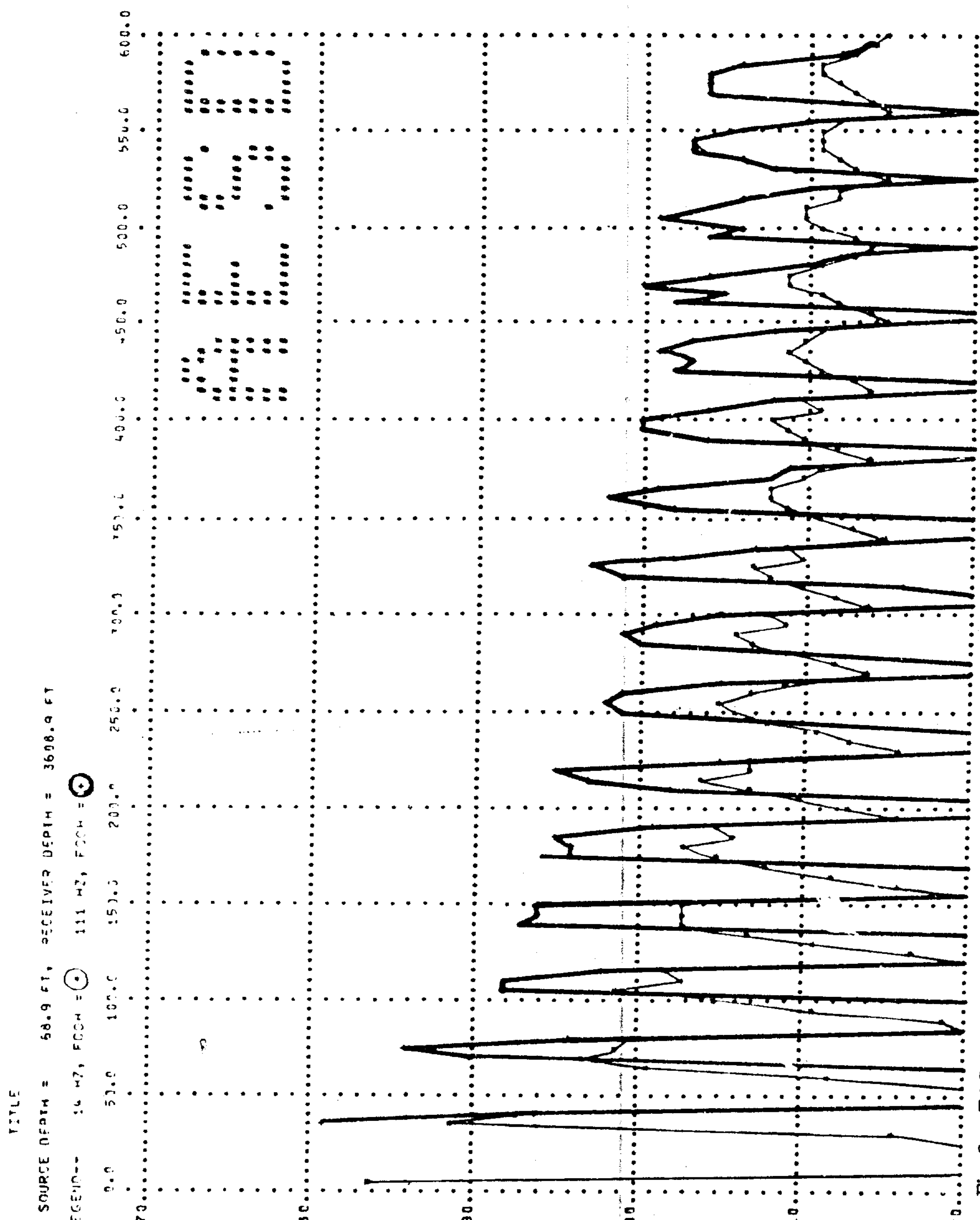

Fig. 8 — FACT calculation of TL (dB) vs Range (n.mi.) for source depth of 21 m with fully coherent summation of rays.

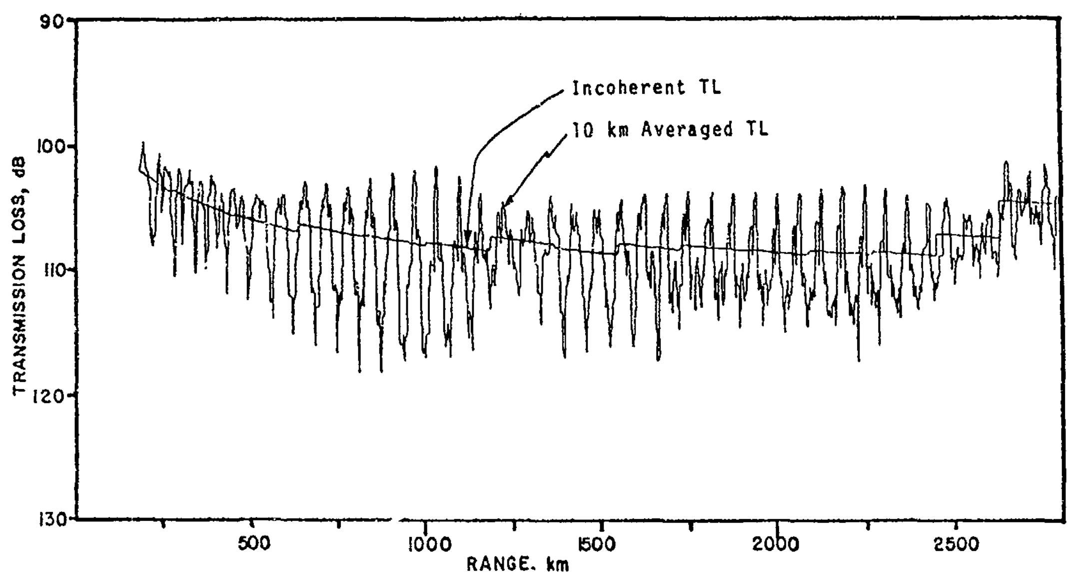

Fig. 9 — Normal mode calculation of TL (dB) vs Range (km) for source depth of 104 m using archival environmental parameters (Climatology results).

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